

# DIGITAL OUTPUT FORCE SENSORS SPI COMMUNICATIONS

## Technical Note

This Technical Note provides implementation information for Honeywell force sensors with SPI (Serial Peripheral Interface) digital output.

### 1.0 INTRODUCTION

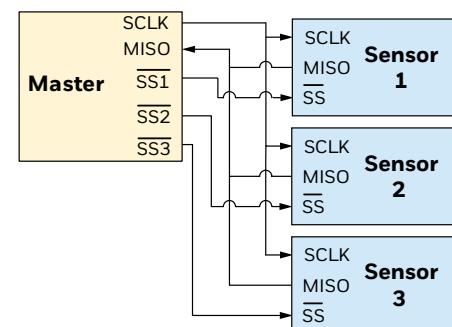
The Serial Peripheral Interface (SPI) is a simple bus system for synchronous serial communication between one “Master” and one or more “Sensors”. It can operate in either full-duplex mode (communication occurs in both directions simultaneously) or half-duplex mode (communication occurs in one direction only). The Master device initiates an information transfer on the bus and generates clock and control signals. The Master controls the Sensors through individual Sensor select lines which are active only when selected.

Honeywell force sensors with SPI output operate in half-duplex mode only, with data transfer from the Sensor to the Master (see Figure 1). Three bus lines must be used for these data transmissions:

1. **SCLK:** Signal Clock
2. **MISO:** Master In/Sensor Out
3. **SS:** Sensor Select

These three bus lines are all unidirectional. The Master controls the SCLK and SS lines while the Sensor controls the MISO line.

FIGURE 1. SPI BUS CONFIGURATION



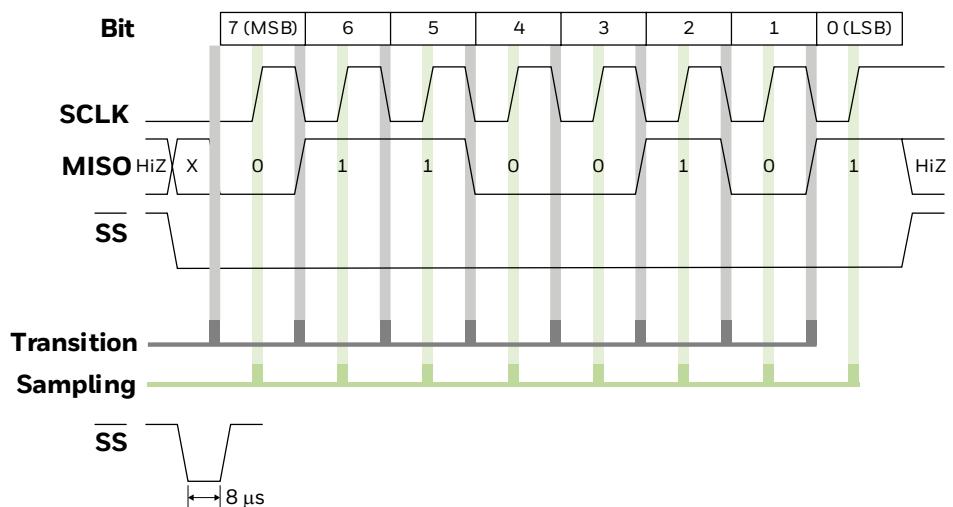
## 2.0 DATA TRANSFER

Communication begins by deasserting the SS bus line. At this point, the sensor is no longer idle and begins to send data once a clock is received.

Honeywell digital output force sensors are configured for operation such that data on the MISO bus line will transition during the falling edge of clock pulses, meaning that the Master device should sample this during the rising edge of the clock pulse.

Figure 2 shows an example of a one byte data transfer from the sensor to the Master. The data 101 (01100101 binary, or 65 hex) is the result of the read. Once the clocking begins, these sensors are designed to output up to four bytes of data, depending on the sensor options and application needs. In all cases, the first two data bytes are the compensated force output, along with sensor status bits. The third and fourth bytes are for the optional compensated temperature output.

**FIGURE 2. EXAMPLE OF A ONE BYTE SPI DATA TRANSFER**

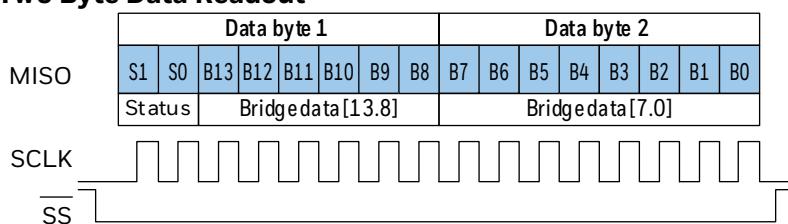


### 2.1 Force Reading (see Figure 3)

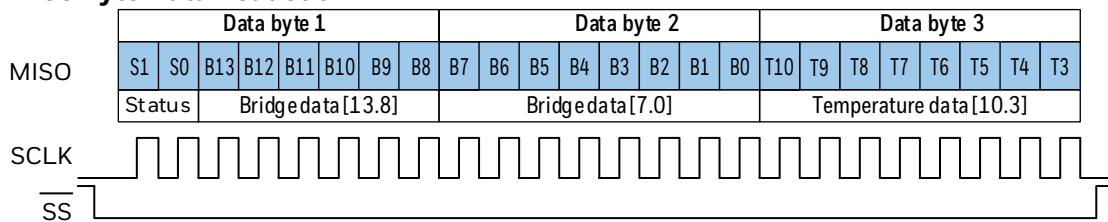
The Master generates the necessary clock signal after activating the sensor with the SS bus line. The sensor will transmit up to four bytes of data: the first two bytes contain the compensated force output and the second two bytes contain the optional compensated temperature output. The Master can terminate the communication by stopping the clock and deactivating the SS bus line.

**FIGURE 3. SPI FORCE AND TEMPERATURE MEASUREMENT PACKETS READOUT<sup>1</sup>**

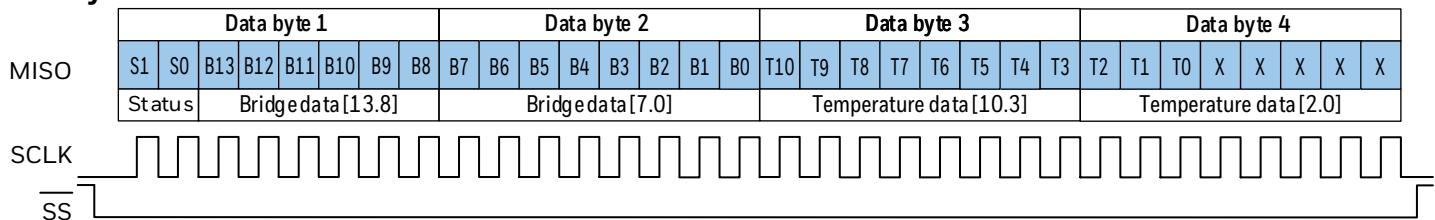
#### Two Byte Data Readout



#### Three Byte Data Readout



#### Four Byte Data Readout



■ Bits generated by Sensor

## 2.2 TEMPERATURE READING

The optional corrected temperature data may be read out with either 8-bit or 11-bit output. See Table 1 for specifics.

**TABLE 1. OPTIONAL COMPENSATED TEMPERATURE**

OUTPUT	READING	LOCATION	RESOLUTION
8-bit	Optional compensated temperature value	third data byte	0.8°C
11-bit	Complete optional compensated temperature value	fourth data byte <sup>1</sup>	0.1°C

<sup>1</sup> The five least significant bits of the fourth data byte are "Do Not Care" and should be ignored.

## 2.3 STATUS BITS

Honeywell digital output force sensors offer both standard and optional diagnostics to ensure robust system operation in critical applications. The diagnostic state is indicated by the first two Most Significant Bits of data byte 1 as shown in Table 2.

**TABLE 2. DIAGNOSTIC STATES**

STATUS BITS		DEFINITION
S1	S0	
0	0	Normal operation, valid data
0	1	Device in command mode <sup>1</sup>
1	0	Stale data: Indicates data that has already been fetched since the last measurement cycle, or data fetched before the first measurement has been completed
1	1	diagnostic condition

<sup>1</sup> Command mode is used for programming the sensor. This mode should not be seen during normal operation.

A status bit reading of "10" indicates "stale" data. This state may occur when the Master polls the data quicker than the sensor can update the output buffer.

### 2.31 Standard Diagnostic Function

The standard diagnostic function is an EEPROM (Electrically Erasable Programmable Read-Only Memory) signature used to validate the EEPROM content during startup. Any EEPROM content change after calibration flags a diagnostic condition.

### 2.32 Optional Diagnostic Functions

The two optional diagnostic functions, either of which may be indicated by a status bit reading of "11", are:

- Loss of sense element connection
- Short circuit of sense element

(Please contact Honeywell Customer Service with questions regarding the availability of optional digital output force diagnostics.)

## 3.0 CALCULATING FORCE FROM THE DIGITAL OUTPUT

The output of the sensor may be expressed by its transfer function as shown in Equation 1:

**Equation 1: Force Sensor Transfer Function**

$$\text{Output} = \frac{(\text{Output}_{\text{max}} - \text{Output}_{\text{min}})}{\text{Rated Force Range}} \times (\text{Force}_{\text{applied}}) + \text{Output}_{\text{min}}$$

Rearranging this equation to solve for force provides Equation 2:

**Equation 2: Force Output Function**

$$\text{Force} = \frac{(\text{Output} - \text{Output}_{\text{min}})}{(\text{Output}_{\text{max}} - \text{Output}_{\text{min}})} \times \text{Rated Force Range}$$

Where:

$\text{Output}_{\text{max.}}$  = output at maximum force [counts]

$\text{Output}_{\text{min.}}$  = output at minimum force [counts]

$\text{Force}_{\text{rated}}$  = maximum value of force range (N, lb, g, or kg)

$\text{Force}_{\text{applied}}$  = force being measured by sensor (N, lb, g, or kg)

$\text{Output}$  = digital force reading [counts]

**Example:** Calculate the force for a 10 N force sensor with a 10% to 90% calibration and a force output of 6880 (decimal) counts:

$$\text{Output}_{\text{max.}} = 14745 \text{ counts} (90\% \text{ of } 2^{14} \text{ counts or } 0x3999)$$

$$\text{Output}_{\text{min.}} = 1638 \text{ counts} (10\% \text{ of } 2^{14} \text{ counts or } 0x0666)$$

$$\text{Force}_{\text{rated}} = 10 \text{ N}$$

$$\text{Force} = \text{force in N}$$

$$\text{Output} = 6880 \text{ counts}$$

$$\text{Force} = \frac{[(6880 - 1638) \times 10]}{(14745 - 1638)}$$

$$\text{Force} = \frac{(5242 \times 10)}{13107}$$

$$\text{Force} = 4 \text{ N}$$

## 4.0 CALCULATING OPTIONAL TEMPERATURE FROM THE DIGITAL OUTPUT

For those sensors so equipped, the optional compensated temperature output may be converted to °C using Equation 3:

### Equation 3: Temperature Conversion Function

$$\text{Temperature (°C)} = \left( \frac{\text{Output (dec)}}{2047} \times 200 \right) - 50$$

If the 8-bit temperature output is used, shift the data to the left by three bits and set the three Least Significant Bits (LSB) to zeros.

**Example:** Calculate the optional compensated temperature output for a sensor with an 8-bit temperature output of 255:

**Step 1:** Left shift the above 8-bit value by three places and append the three LSBs with zeros:

$$\begin{aligned} \text{Digital Temperature Output (8-bit)} &= 255 = \\ &11111111b \\ &11111111000b = 2040 \end{aligned}$$

**Step 2:** Use the adjusted value and insert into Equation 3:

$$\text{Temperature (°C)} = \left( \frac{2040}{2047} \times 200 \right) - 50$$

$$\text{Temperature} = 149.31^\circ\text{C}$$

**Example:** Calculate the optional compensated temperature for a sensor with an 11-bit temperature output of 1456:

**Step 1:** Insert the digital temperature output value into Equation 3:

$$\text{Temperature (°C)} = \left( \frac{1456}{2047} \times 200 \right) - 50$$

$$\text{Temperature} = 92.26^\circ\text{C}$$

## 5.0 TIMING AND LEVEL PARAMETERS (SEE FIGURE 4 AND TABLE 3)

### FIGURE 4. TIMING AND LEVEL PARAMETERS

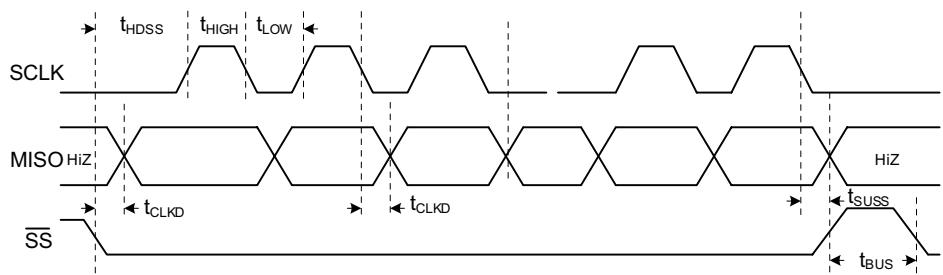


TABLE 3. TIMING AND LEVEL PARAMETERS

PARAMETER	SYMBOL	MINIMUM	TYPICAL	MAXIMUM	UNIT
SCLK clock frequency	$f_{SCL}$	50	—	800	kHz
SS drop to first clock edge	$t_{HDSS}$	2.5	—	—	$\mu\text{s}$
Minimum SCLK clockwidth <sup>1</sup> :					
low	$t_{LOW}$	0.6	—	—	$\mu\text{s}$
high	$t_{HIGH}$	0.6	—	—	$\mu\text{s}$
Clock edge to data transition	$t_{CLKD}$	0	—	—	$\mu\text{s}$
Rise of SS relative to last clock edge	$t_{SSUS}$	0.1	—	—	$\mu\text{s}$
Bus free time between rise and fall of SS	$t_{BUS}$	2	—	—	$\mu\text{s}$
Output level:					
low	$\text{Out}_{LOW}$	—	0	0.2	$V_{DD}$
high	$\text{Out}_{HIGH}$	0.8	1	—	$V_{DD}$

<sup>1</sup>Combined low and high widths must equal or exceed minimum SCL period.

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Asia Pacific	+65 6355-2828
Europe	+44 1698 481481
USA/Canada	+1-800-537-6945

**Honeywell**  
**Sensing and Internet of Things**  
830 East Arapaho Road  
Richardson, TX 75081  
[honeywell.com](http://honeywell.com)

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